

Control of Agent-Based Systems

Technical Overview

March 1999

*Controlling the run-time integration of
heterogeneous systems*

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Control of Agent-Based Systems

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- **DARPA Major Focus Areas**

Comprehensive Awareness, Mobile C3I

- **Theme**

Agent-Based Computing

- **Thesis**

Agents are a key technology for providing semantic interoperability between heterogeneous systems without enforcing a predetermined standard, but control mechanisms are needed to scale them significantly beyond current practice.

- **Task Areas**

**Team
Coordination
and Cooperation**

**Alternate Control
Strategies**

**Mobility and
Scaling**

**Agent
Capabilities
and
Applications**

What is an “agent”?



*The term “agent” can mean
many different things*

- Mobile Code
- Distributed component libraries
- “Disembodied” code with temporal duration or persistent state
- “Intelligent routers”
- Web Search Tools
- Semantic broker and name space services
- Electronic commerce with message-passing entities
- Robots
- Interface animation
- Applets
- Dynamic services
- Control protocols

What is an “agent”?

CoABS will unify key technologies from several software communities

- Avoiding those being heavily worked by other groups at DARPA or in industry
- Focusing on key needs of the modern military

- Mobile Code

- ~~Distributed component libraries~~

- “Disembodied” code with temporal duration or persistent state

- ~~“Intelligent routers”~~

- ~~Web Search Tools~~

- Semantic broker and name space services

- ~~Electronic commerce with message-passing entities~~

- ~~Robots~~

- ~~Interactivity animation~~

- ~~Applets~~

- Dynamic services

- Control protocols

Agents and the military need



Many programs have needs for many aspects of agents

- Assignment problems ↔ Auction mechanisms
- Bursty bandwidth use ↔ Mobile code
- Open source information ↔ Info agents
- Inteoperability ↔ Brokering
- Etc.

What will be the focus of CoABS?

- Examining these technologies in the context of an evolving military information management vision
 - ◆ AFSAB Information Management, AF C2 Conops
 - ◆ Army after next
 - ◆ Cooperative Engagement Capability
 - ◆ And numerous others

CoABS will help fulfill this vision!

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Current Capabilities

- Limited connection to legacy systems
- Human-mediated information fusion
- In place comms, forward footprint, little reachback
- Broadcast-based push models
- Limited sharing of structured data

CoABS

- *Brokering and name services for legacy wrappers*
- *“disembodied” filtering and fusion*
- *Mobile code for reachback and mobility support*
- *Control Protocols*
- *Structural semantics*

Military Needs

- Total integration with legacy systems
- Automated info filtering & fusion
- Dynamic comms, AEA Conops
- Precision Guided Information (PGI)
- Seamless sharing of unstructured sources

Adaptive Connectivity (AC)

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Connection is Dynamic

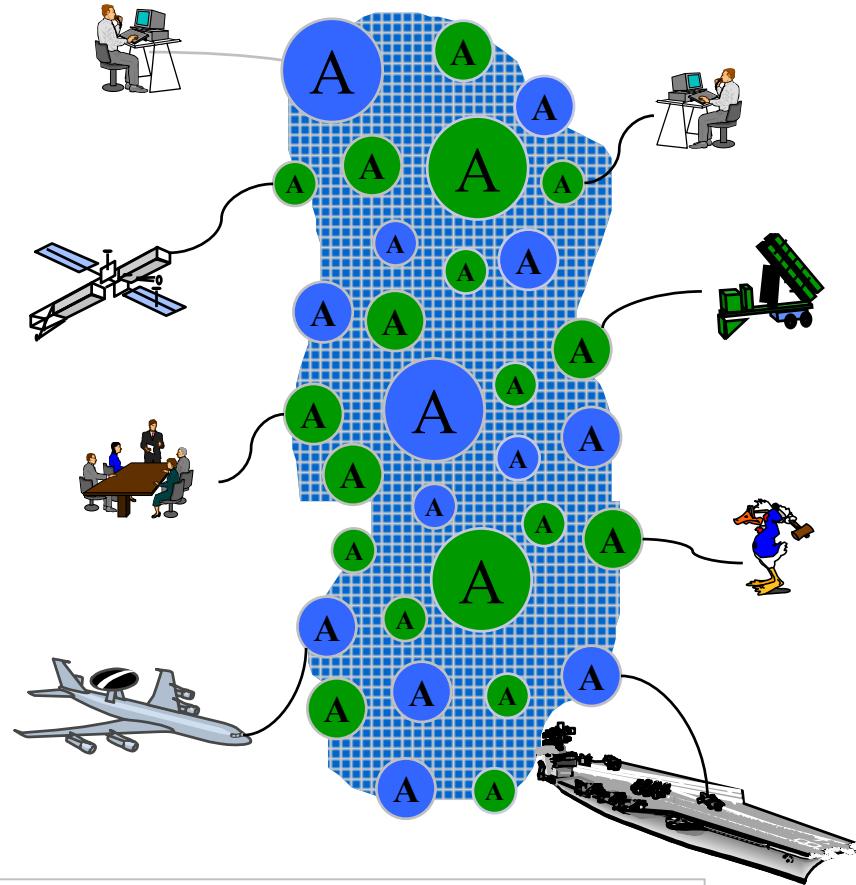
- Information sources bootstrapped
- Protocol negotiation
- Reaction after connecting

Agents broker network services

- Adapt to bandwidth and resources
- Control agent interaction
- Use mobility as appropriate

Heterogeneity is assumed

- Multiple standards and interfaces
- Semantics negotiated at run time

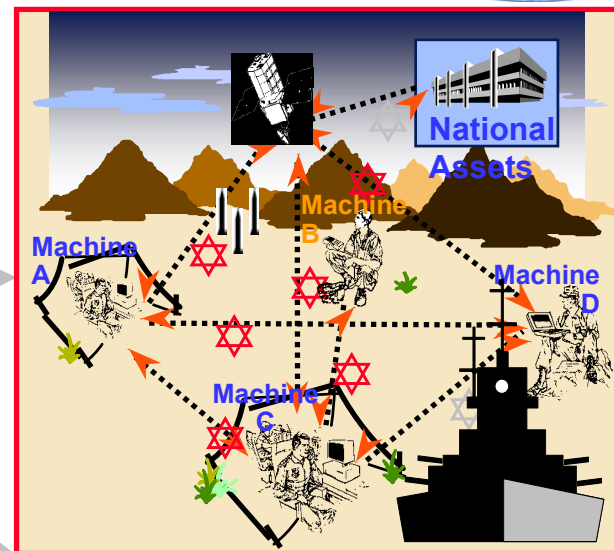


Research that focuses on the integration and scaling of these technological pieces is necessary to provide interoperability between heterogeneous systems in a dynamic operational environment!!

How do we get there?

Military TIEs stress *integration*

- OOTW
 - ◆ Neo-Challenge Problems defined
- Ballistic and Theatre Missile Defense
 - ◆ TMD demoed at Bravo Warrior
- Coalition Force Interoperability
 - ◆ Int'l Workshop on Coalition Planning 5/99

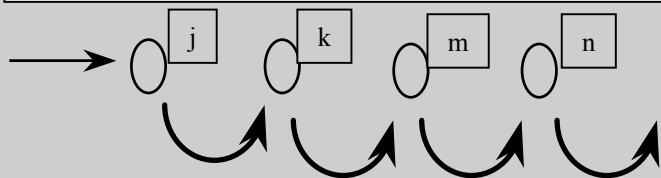


Scientific TIEs stress *scaling*

- Negotiation Experiments
 - ◆ 1st results favor auctions
- Mathematical Analyses
 - ◆ New results for agent mobility
- Control Scheme Comparison
 - ◆ Analysis of time/ Experiments designed

Site j "costs" c_j to visit and has probability p_j of success.

Visit sites until none left or successful.



$$\text{Expected cost} = c_j + (1-p_j)c_k + (1-p_j)(1-p_k)c_m + \dots$$

OOTW: NEO Challenge Problems

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Defined three critical NEO elements as challenge problems

Year 1:

- ↓ Individual teams for each problem

Year 2:

- ↓ separate solutions integrated for NEO scenario
- ↓ Teams to work with military users with same issues

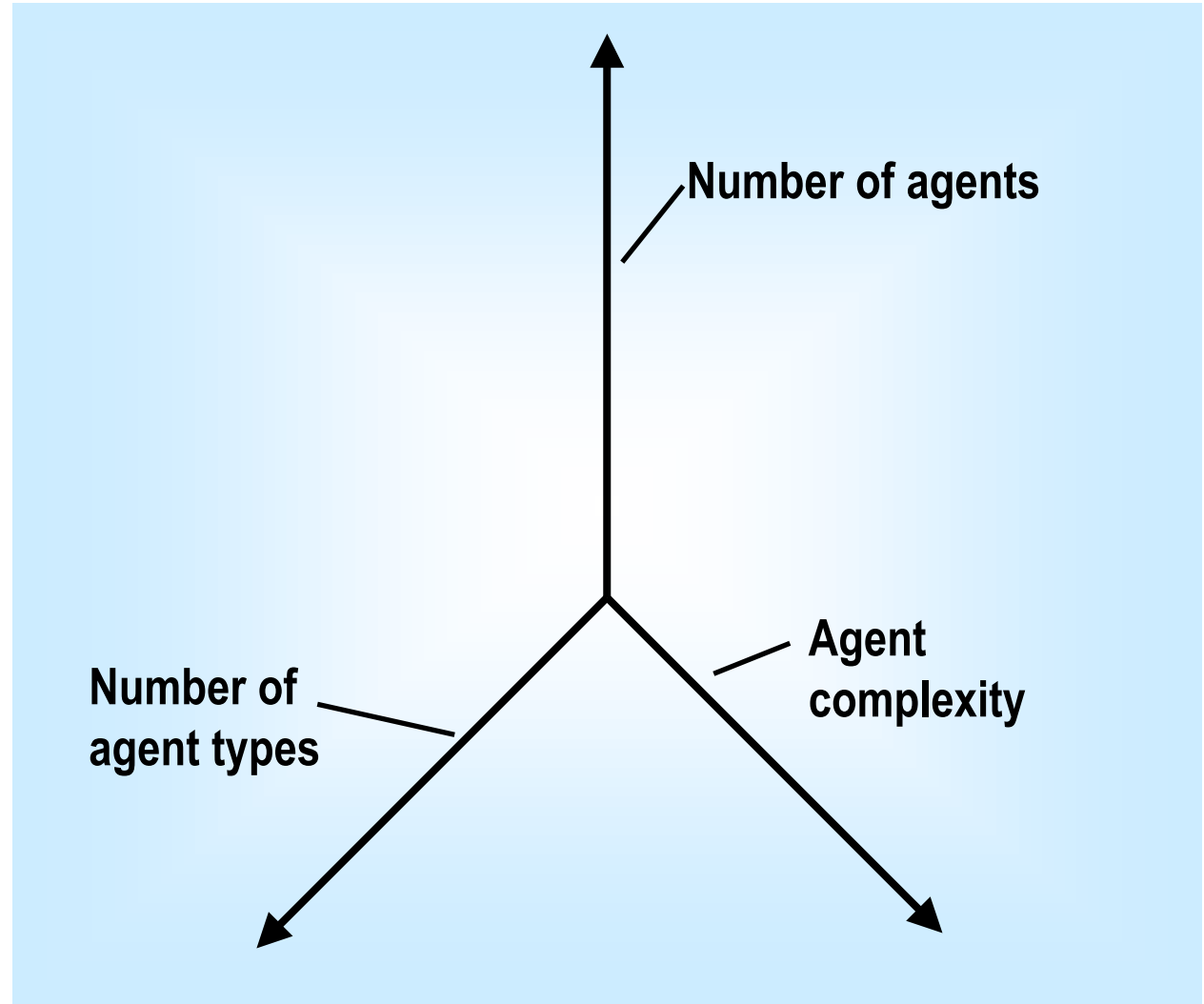
Three teams:

- **Plan Failure: Must use helicopters, instead of commercial air, to evacuate**
 - ◆ Team coordination of copters
 - ◆ Interagent communication policies
- **Distributed Planning: Coordinate evacuation planning between embassy and CONUS planners**
 - ◆ Heterogeneity
 - ◆ Human-agent interaction
 - ◆ Robustness to QoS
- **Open Source Search: Find US citizens in evacuation areas**
 - ◆ Coordinate transformation
 - ◆ Semantic interoperability
 - ◆ Open source info agents

Agent Scaling Experiments

3 Key aspects of an agent system

- ◆ # of agents
- ◆ # of agent types
- ◆ Complexity (# of actions an agent could take)



Agent Scaling Experiments

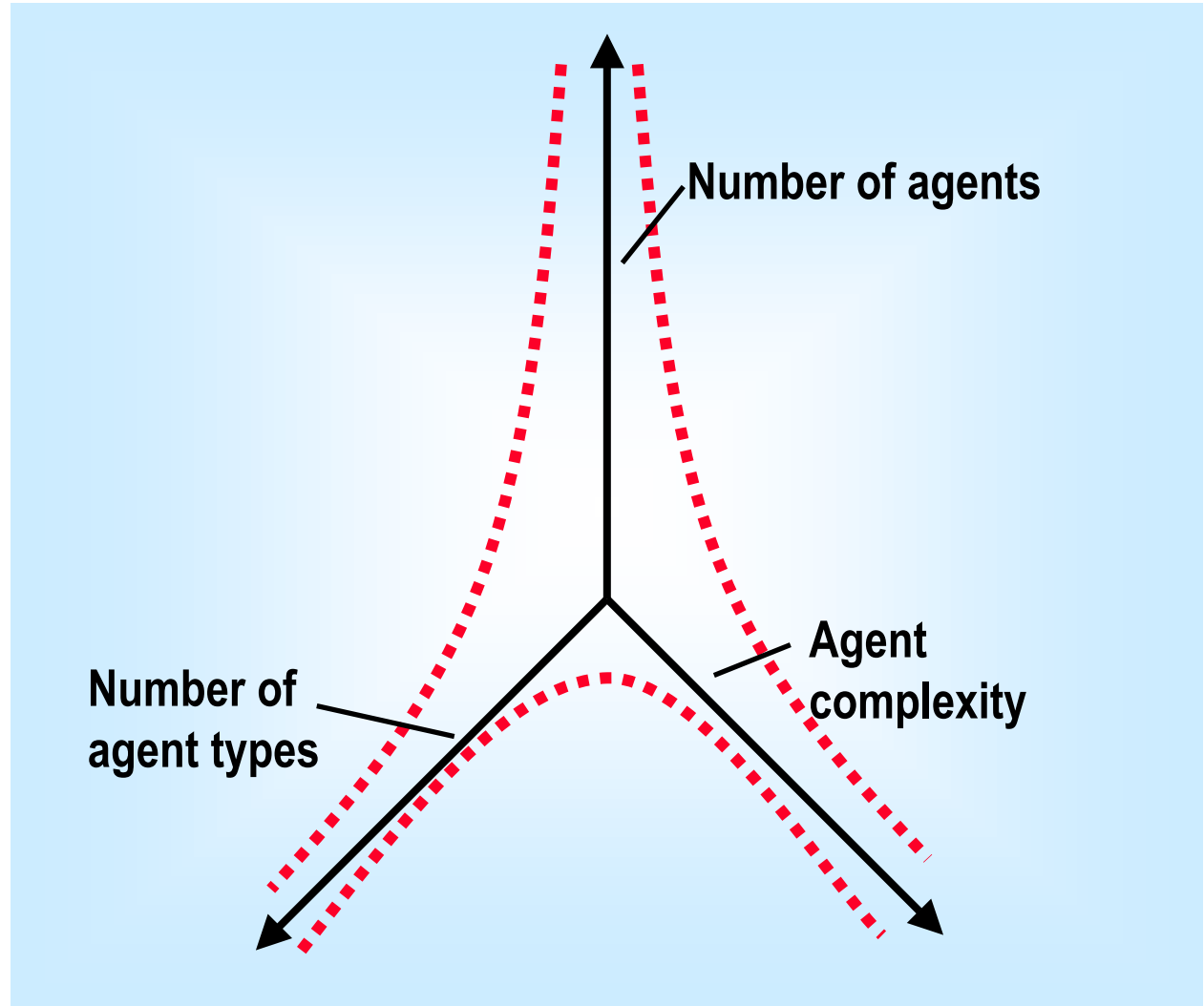
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3 Key aspects of an agent system

- ◆ # of agents
- ◆ # of agent types
- ◆ Complexity (# of actions an agent could take)

Current experiments cluster near the axes on the orthogonal planes!!



Agent Scaling Experiments

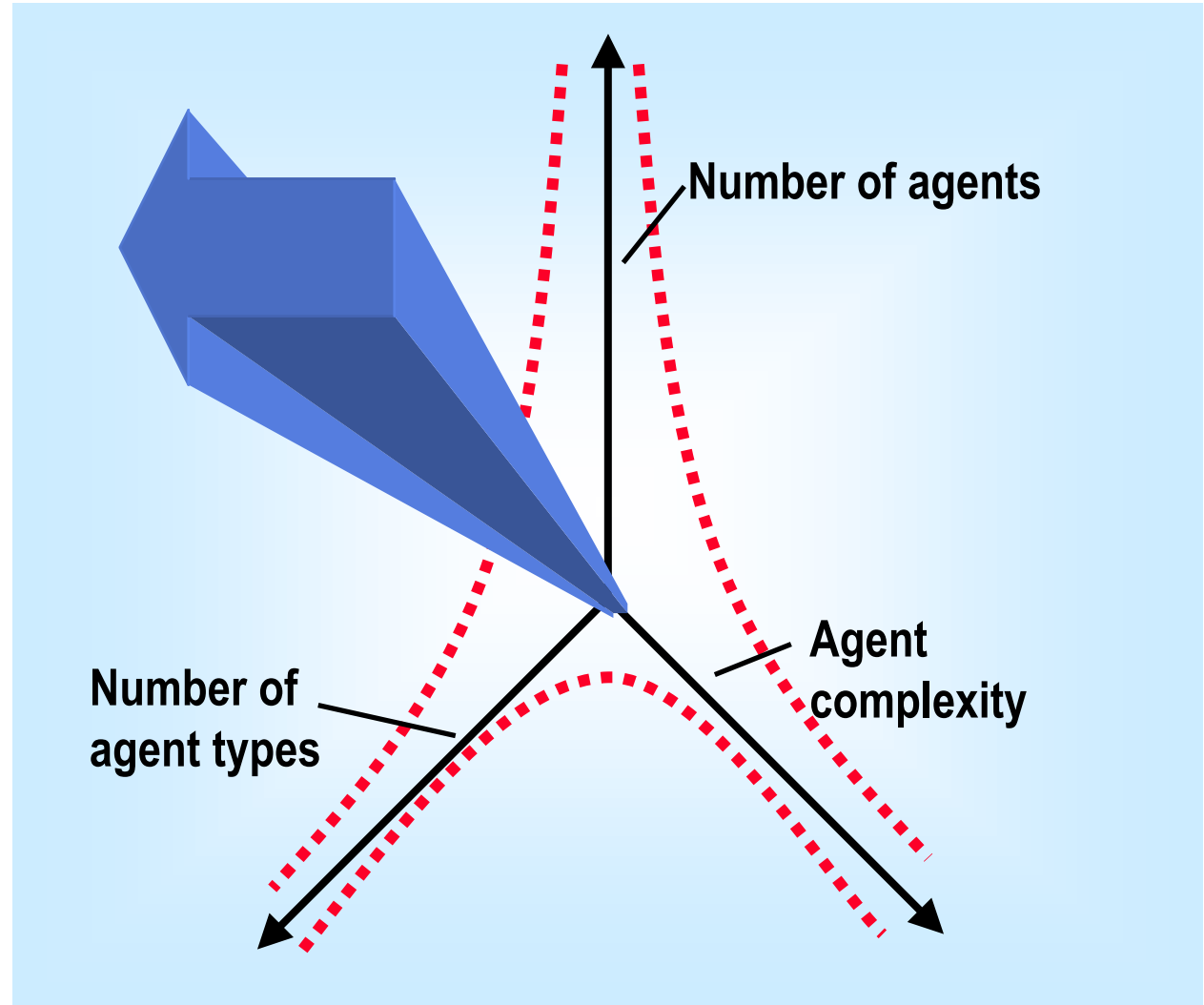
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3 Key aspects of an agent system

- ◆ # of agents
- ◆ # of agent types
- ◆ Complexity (# of actions an agent could take)

CoABS will show that we can get out into the middle of this space!



Putting it all together



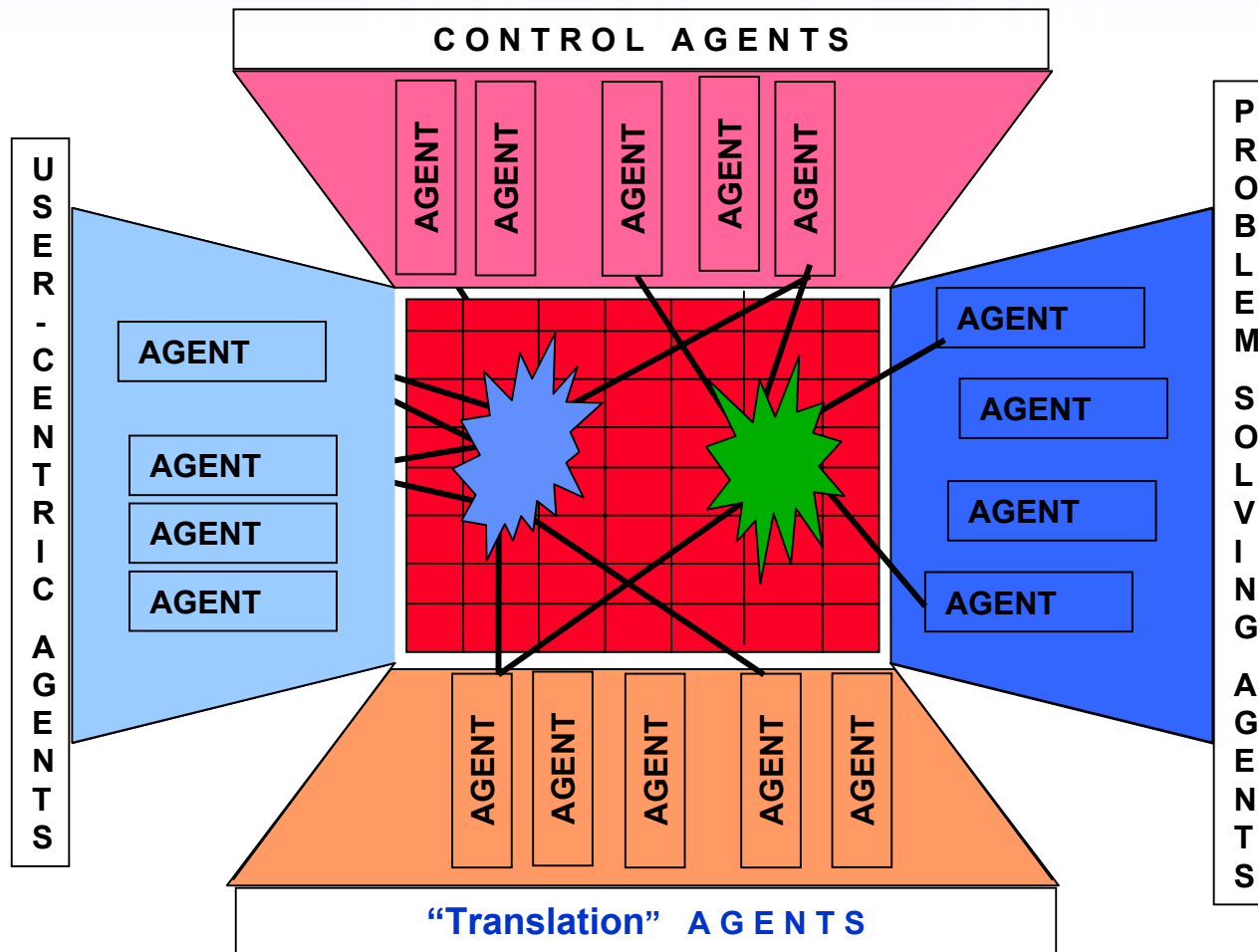
To enable this research, and to provide transition to military users, the CoABS program will design, implement, and test a prototype “agent grid”

- **Stresses run-time interoperability**
 - ◆ **Of diverse systems**
 - ◆ **Of diverse agent types**
 - **Problem solving agents**
 - **User Interface agents**
 - **Broker, visualization, and other control agents**
 - **Translation agents**

Unifying Infrastructure

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A unifying infrastructure will allow a number of different types of agents to provide a wide range of services negotiated at run-time.

The CoABS Grid



Apply software engineering “best-practices” to position agent technology as a viable software solution to real-world problems

- ◆ Stressing the run-time integration of systems
 - ◆ Build on existing agent standards as design baseline
 - ◆ Apply emerging internet technologies & standards to maximize interoperability and flexibility
 - IIOP
 - Jini
 - Java
 - LDAP
 - RMI
 - ◆ Leverage and incorporate CoABS contributions
 - ◆ Influence standards organizations

Concepts

Agent

- An encapsulated software entity with its own identity, state, behavior, thread of control, and ability to interact and communicate with other entities including people, other agents, and legacy systems

Grid Registered Agent

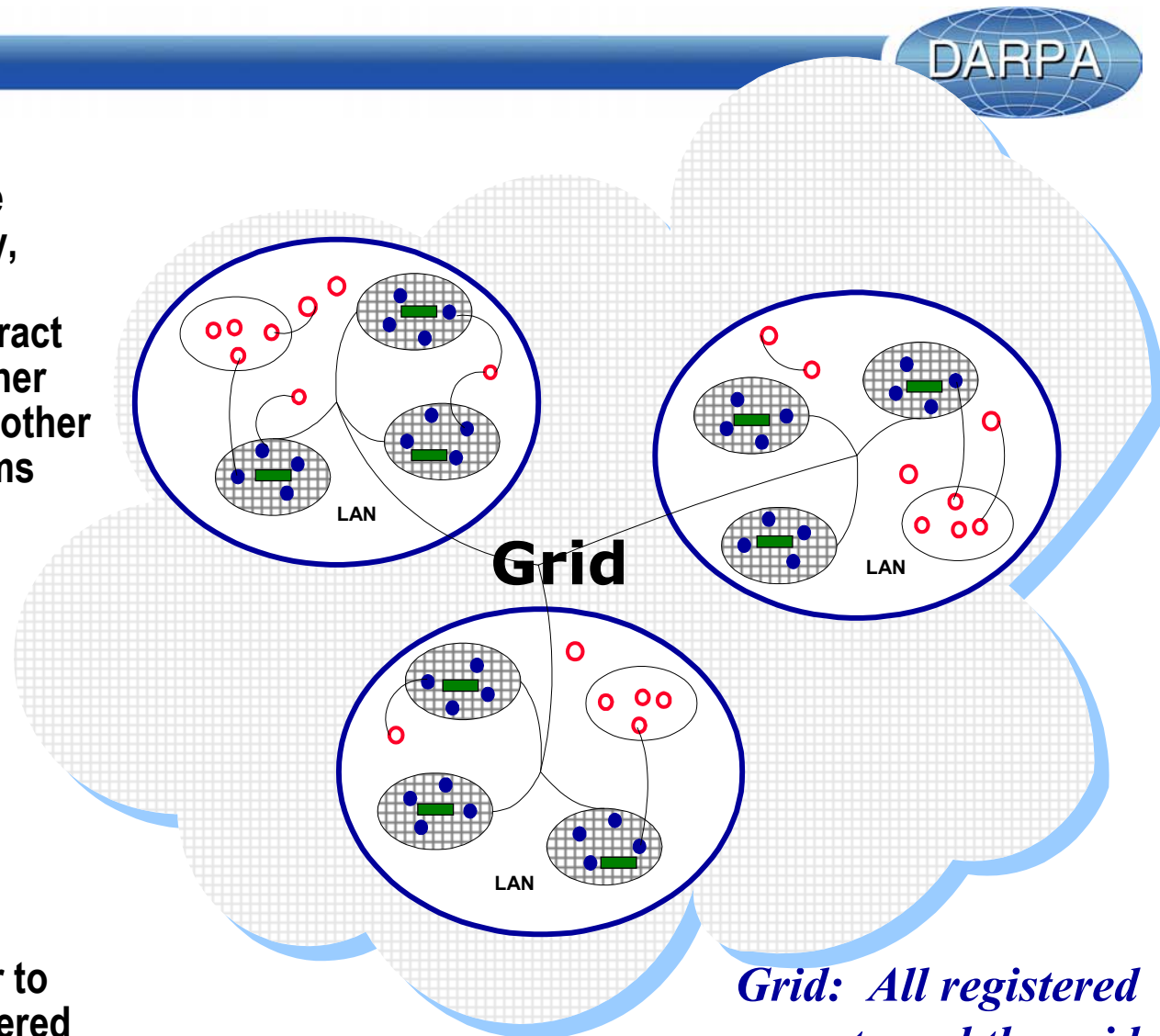
- Agent registered with grid services

Grid Agent Platform

- Set of Grid services and registered agents

Grid Services

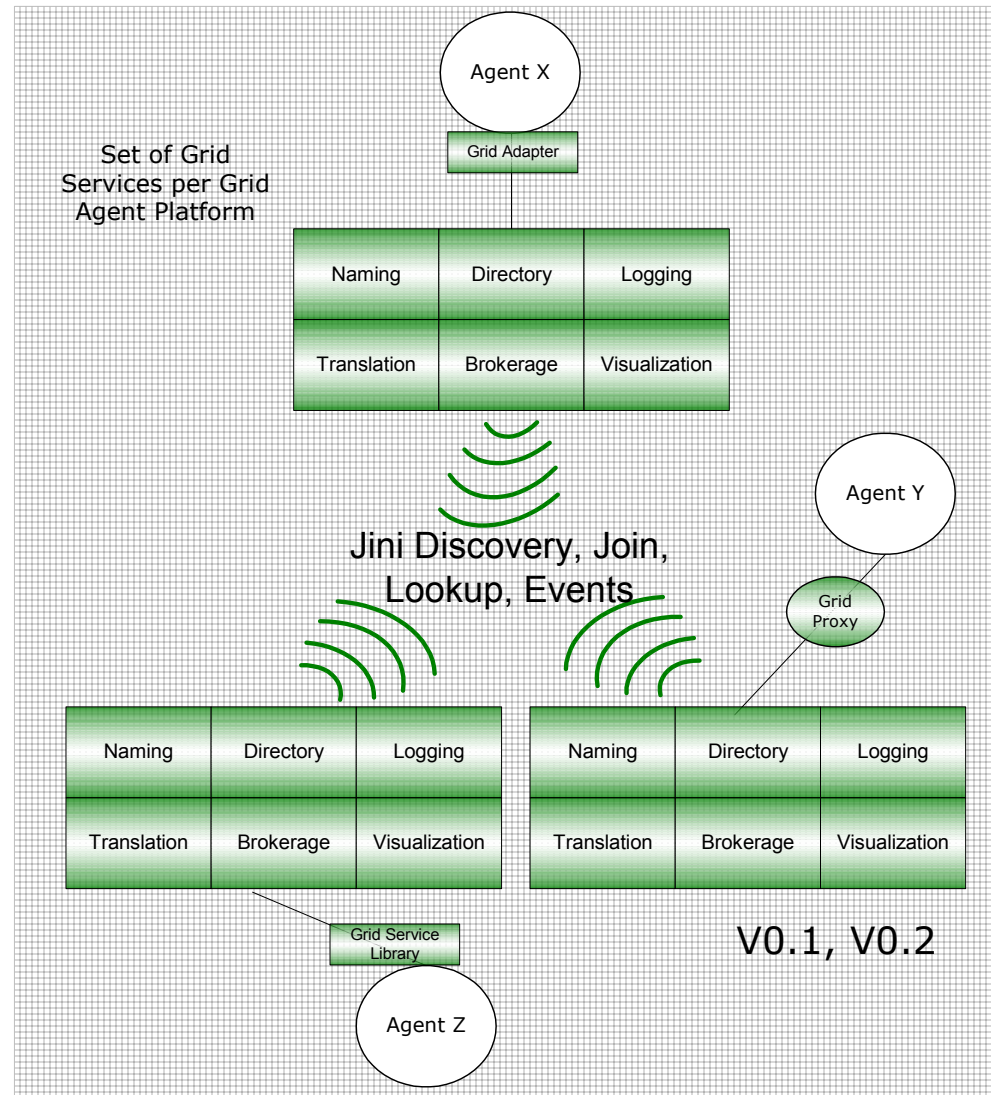
- Infrastructure agents that cooperate with each other to provide services to registered agents



Grid: All registered agents and the grid services federation

Prototype Grid Architecture

- **Grid services enable the federation of distributed heterogeneous agents to interoperate and collaborate**
 - ♦ Example: OAA agent collaborates with a RETSINA agent across the network
- **Agents register their names and capabilities using**
 - ♦ Naming service
 - ♦ Directory service
- **Agents use the brokerage service to find other agents that can deal with a specified request**
- **Agent activity within the grid is recorded using a logging service**
- **Agent status and interaction within the grid is represented using a visualization service**
- **Grid service interaction is conducted using FIPA ACL**
- **Translation supports**
 - ♦ RETSINA KQML
 - ♦ OAA ICL



V0.1, V0.2

Translation/Language Issues

<u>Performative</u>	<u>Service</u>	<u>Control Add-ins</u>	<u>Content</u>
Request-service	Buy (Flowers)	<ul style="list-style-type: none"> •Economic information •Language info •Data sources •Mobility •etc 	#Dollar-UnitedStates isa: #StandardUnitOfMeasure #UnitOfMeasureNoPrefix #UnitOfMoney #FloweryPlant #BiologicalTaxon #FloweringPlant. isa: #ExistingObjectType #TemporalObjectType genls: #FloweringPlant

Performative: Services between agents (Ask, Register, etc.)

Service: “Structural” semantics needed (classes, relations)

Control Add-ins: Agent specific, system dependent

Content: “Heavy weight” semantics (domain specific ontology)

Agent communication languages, ACLs, actually cover a number of different areas, often conflated together, adding to the confusion.

CoABS Plans (FY99)

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Continue DARPA presence with Industry agent efforts

- Continue leadership role in OMG, FIPA
 - ◆ Develop the necessary infrastructure and protocols to enable the effective transition of the best agent control strategies into commercial and defense systems.

Begin transition from Integration TIEs to demonstrations

- Demonstration development in NEO domain avoids KA issues
 - ◆ Demonstrate novel agent technologies at summer meeting
 - ◆ Program Mgt will team with military users based on fits with these demonstrated technologies

Push scaling TIEs to focus on key needs

- Perform experiments to analyze which aspects of agent control scale best, provide best quality of service, and are most efficient for information routing problems.
 - ◆ Teams to show results at summer meeting
 - ◆ Program mgt to select best and set up follow-ons